NACA

RESEARCH MEMORANDUM

for the

Bureau of Aeronautics, Department of the Navy

SUPPLEMENTARY INVESTIGATION IN THE FREE-SPINNING TUNNEL OF A 1/24-SCALE MODEL OF THE GRUMMAN F9F-6 AIRPLANE INCORPORATING ONLY FLAPERONS FOR LATERAL CONTROL

TED NO. NACA DE 364

By Walter J. Klinar and Henry A. Lee

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

A supplementary investigation was conducted in the Langley 20-foot free-spinning tunnel on a 1/24-scale model of the Grumman F9F-6 airplane. The primary purpose of the investigation was to reevaluate the spin-recovery characteristics of the airplane in view of the fact that the ailerons had been eliminated from the flaperon-aileron lateral control system of the airplane. A spin-tunnel investigation on a model of the earlier version of the F9F-6 airplane had indicated that use of ailerons with the spin (stick right in a right spin) was essential to insure recovery.

The results indicate that with ailerons eliminated, it may be difficult to obtain an erect developed spin but if a fully developed spin is obtained on the airplane, recovery therefrom may be difficult or impossible. Flaperon deflection should have little effect on spins or recoveries.

INTRODUCTION

At the request of the Bureau of Aeronautics, Department of the Navy, a supplementary investigation was made in the Langley 20-foot free-spinning tunnel on a 1/24-scale model of the Grumman F9F-6 airplane. During the development of the airplane, ailerons were eliminated from the lateral control system and the span of the original flaperons (spoiler ailerons)

[redacted]

was increased. Because spin-tunnel results on an original F9F-6 model (ref. 1) had indicated that aileron movement to full with the spin (stick right in a right spin) in conjunction with rudder reversal was necessary to insure recovery from a developed erect spin, a supplementary investigation was deemed desirable to evaluate the effect on spin recovery of eliminating ailerons and increasing the flaperon span on the airplane.

SYMBOLS

b	wing span, ft
$\bar{c}$	mean aerodynamic chord, ft
$x/\bar{c}$	ratio of distance of center of gravity rearward of leading edge of mean aerodynamic chord to mean aerodynamic chord
$z/\bar{c}$	ratio of distance between center of gravity and fuselage reference line to mean aerodynamic chord (positive when center of gravity is below line)
m	mass of airplane, slugs
I_X, I_Y, I_Z	moments of inertia about X, Y, and Z body axes, respectively, slug-ft^2
$\frac{I_X - I_Y}{mb^2}$	inertia yawing-moment parameter
$\frac{I_Y - I_Z}{mb^2}$	inertia rolling-moment parameter
$\frac{I_Z - I_X}{mb^2}$	inertia pitching-moment parameter
ρ	air density, slug/cu ft
μ	relative density of airplane, $\frac{m}{\rho Sb}$
α	angle between fuselage reference line and vertical (approximately equal to absolute value of angle of attack at plane of symmetry), deg

ϕ	angle between span axis and horizontal, deg
V	full-scale true rate of descent, ft/sec
Ω	full-scale angular velocity about spin axis, rps

MODEL

The 1/24-scale model used in the supplementary investigation was built and prepared for testing at the Langley Laboratory of the National Advisory Committee for Aeronautics. A three-view drawing of the model is presented in figure 1. A photograph of the model is shown in figure 2. A small flap located on the left wing of the airplane for lateral trim and designated as a trimmer was included on the model (fig. 1).

The normal maximum deflections of the controls were as follows (measured perpendicular to the hinge lines):

Rudder:	
Upper, deg	±19
Lower, deg	±25
Elevator, deg	30 up, 15 down
Flaperons, deg	55 up
Lateral trimmer (on left wing)	15 up, 15 down

The dimensional characteristics of the airplane represented by the model are given in table I. The mass characteristics are given in table II.

An appendix is included which presents a general description of the model testing technique, the precision with which model test results and mass characteristics are determined, variations in model mass characteristics occurring during tests, a general comparison between model and airplane results.

RESULTS AND DISCUSSION

Erect Spins

The results of the investigation are presented in charts 1 and 2 and in table III. The model was in the normal flight loading (loading 1 in table II) for all tests and tests were conducted with the model in the clean condition unless otherwise indicated. Inasmuch as there was a slight difference in model results to the right and left, the results

which are presented were those obtained in the direction giving somewhat conservative values. The results of the current investigation were obtained primarily at an equivalent test altitude of 25,000 feet (ρ = 0.001065 slug/cu ft). Brief tests conducted at 15,000 feet (used for the tests reported in ref. 1) indicated that the model was less inclined to spin at this altitude than at the higher altitude. The data presented in chart and tabular form, therefore, are for the 25,000-foot test altitude.

An analysis of the results of the model tests indicates that erect spins may be difficult to obtain on this airplane, but those that are obtained will probably be very oscillatory, primarily in roll and yaw. Recovery from the developed spin may be difficult or impossible. The pilot should be alerted against allowing a spin to develop. The results indicate that the best chance for recovery from a developed spin will prevail if the rudder is reversed to full against the spin during the steepest phases of the spin. The stick should be held full back until rotation slows down appreciably and then moved forward. To insure recovery it appears that this airplane would require incorporation of ailerons into the design (as had the original version, ref. 1) inasmuch as the flaperons alone were ineffective in the spin. Whereas ailerons incorporated into the design might aid in the attainment of a spin when displaced against the spin as is indicated in reference 1, movement of ailerons to full with the spin (stick right in a right spin) in conjunction with full rudder reversal should provide satisfactory recoveries.

Extending slats (chart 2) had a somewhat favorable effect, and if possible on the airplane, slats should be extended in any spin obtained to expedite recovery. Although a wide variance in turns for recovery after successive recovery attempts was obtained with slats retracted (chart 1), turns for recovery with slats extended were fairly consistent. This is probably attributable to the reduced range of roll and yaw oscillations generally obtained when slats were extended.

Brief tests and analysis indicate that deflection of the lateral trimmer (on the left wing) will have little effect on a left spin, but that if the airplane were in a right spin, deflection of the trimmer full down might have a slight beneficial effect.

Results of tests to determine the size tail parachute required for emergency spin recovery (table III) indicated that a 13-foot-diameter (laid out flat) tail parachute with a drag coefficient of 0.7 (based on flat area) would be required to insure recovery from a fully developed spin by parachute action alone. This is somewhat larger than that indicated in reference 1 for the original F9F-6 design probably because of the higher test altitude used for the present model. It appears that the towline should have a length no longer than the span nor shorter than the semispan. Model tests were conducted with the towline attached below

the jet exhaust and indicated a great tendency for the towline to foul on the tails. As is indicated in reference 1, it appears that the towline should be attached above the horizontal tail to prevent fouling and that the parachute should be ejected positively into the airstream. At the request of the contractor, tests were also made in which the rudder was reversed in conjunction with use of the parachute. The model test results showed that satisfactory recoveries would be obtained if the pilot fully reversed the rudder when using a 9-foot-diameter (laid out flat) tail parachute with a drag coefficient of 0.7 (based on flat area). On the basis of these results it appears that the $7\frac{1}{2}$-foot hemispherical parachute with a drag coefficient of 1.1 (based on the projected area) proposed for use on the airplane by the contractor would also be adequate provided the pilot fully reverses the rudder at the time the parachute is used.

Landing Condition

Current military specifications require airplanes to be spin-demonstrated in the landing condition from only a 1-turn (or incipient) spin, and inasmuch as spin-tunnel test data are obtained for fully developed spins, the landing condition was not investigated on the model. Recovery characteristics in the landing condition may be of significant importance, however, because stall tests of an airplane, generally made at altitude in the landing condition early during the flight test program, may result in an inadvertent spin. Analysis indicates that, although recoveries from fully developed spins may be unsatisfactory (based on the results of tests with many models to determine the effect of landing gear and flaps as analyzed in ref. 2), the F9F-6 airplane should recover satisfactorily from an incipient spin in the landing condition. Therefore, if a spin is inadvertently entered in the landing condition at any time, the flaps and landing gear should be retracted and recovery attempted immediately.

Inverted Spins

Inverted spin tests were not made but analysis shows that, as indicated in reference 1, full reversal of the rudder should terminate inverted spins satisfactorily.

CONCLUSIONS

Based on the results of a supplementary investigation of a 1/24-scale model of the Grumman F9F-6 airplane and on the original results presented

in reference 1, the following conclusions regarding spin and recovery characteristics of the airplane are made:

1. Erect developed spins may be difficult to obtain on the airplane but those that are obtained will generally be very oscillatory primarily in roll and yaw. The oscillations may become so violent that the airplane will oscillate out of the spin without movement of the controls. The oscillatory spin may persist, however, and if it does, satisfactory recovery may not be possible. The pilot should be alerted to prevent the spin from progressing to the fully developed stage. For optimum recovery from a developed spin, the rudder should be moved to full against the spin during the steepest phases of the spin and held there; the stick should be held full back until rotation slows down appreciably then moved forward.

2. Flaperon deflection should have little effect on spins or recoveries.

3. Elimination of ailerons on this design has impaired the spin-recovery characteristics of the airplane.

4. The tendency to spin will be somewhat greater at an altitude of 25,000 feet than at an altitude of 15,000 feet.

5. If an emergency spin-recovery tail parachute can be mounted on the airplane in a manner to insure against fouling, the size parachute required to insure recovery by parachute action alone would be one having a diameter of 13 feet (laid out flat) and having a drag coefficient of 0.7 (based on flat area). The towline should have a length no longer than the wing span nor shorter than the semispan. The towline should be attached above the horizontal tail to prevent fouling and the parachute should be ejected positively into the airstream. If it can be certain that the pilot can and will reverse the rudder fully at the time the parachute is used, a parachute of 9-foot diameter (laid out flat) with a drag coefficient of 0.7 will be adequate.

6. Extending slats should be somewhat favorable and if possible on the airplane, they should be extended in a spin to increase the chances for recovery.

7. Recovery from inverted spins should be satisfactory provided the rudder is reversed to full against the spin.

8. If a spin is inadvertently entered in the landing condition, it is recommended that flaps and landing gear be retracted and recovery attempted immediately.

Langley Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 18, 1954.

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APPENDIX

METHODS AND PRECISION

Model Testing Technique

The operation of the Langley 20-foot free-spinning tunnel is generally similar to that described in reference 3 for the Langley 15-foot free-spinning tunnel except that the model-launching technique is different. With the controls set in the desired position, a model is launched by hand with rotation into the vertically rising airstream. After a number of turns in the established spin, a recovery attempt is made by moving one or more controls by means of a remote-control mechanism. After recovery, the model dives into a safety net. The tests are photographed with a motion-picture camera. The spin data obtained from these tests are then converted to corresponding full-scale values by methods described in reference 3.

Spin-tunnel tests are usually performed to determine the spin and recovery characteristics of a model for the normal spinning-control configuration (elevator full up, lateral controls neutral, and rudder full with the spin) and for various other lateral control and elevator combinations including neutral and maximum settings of the surfaces. Recovery is generally attempted by rapid full reversal of the rudder, by rapid full reversal of both rudder and elevator, or by rapid full reversal of the rudder simultaneously with moving ailerons or other lateral controls to full with the spin. The particular control manipulation required for recovery is generally dependent on the mass and dimensional characteristics of the model (refs. 4 and 5). Turns for recovery are measured from the time the controls are moved to the time the spin rotation ceases and the model enters a dive or a vertical aileron roll. Recovery characteristics of a model are generally considered satisfactory if recovery attempted from or near the normal spinning control configuration by full or nearly full movement of the controls in any of the manners described is accomplished within $2\frac{1}{4}$ turns. This value has been selected on the basis of full-scale-airplane spin-recovery data that are available for comparison with corresponding model test results.

For spins in which a model has a rate of descent in excess of that which can readily be obtained in the tunnel, the rate of descent is recorded as greater than the velocity at the time the model hit the safety net; for example, >300 feet per second, full scale. In such tests, the recoveries are attempted before the model reaches its final steeper attitude and while it is still descending in the tunnel. Such results are considered conservative; that is, recoveries are generally not as fast

as when the model is in the final steeper attitude. For recovery attempts in which a model strikes the safety net while it is still in a spin, the recovery is recorded as greater than the number of turns from the time the controls were moved to the time the model struck the net, as >3. A >3-turn recovery, however, does not necessarily indicate an improvement over a >7-turn recovery. When a model recovers without control movement (rudder held with the spin), the results are recorded as "no spin."

For spin-recovery parachute tests, the minimum-size tail parachute required to effect recovery within $2\frac{1}{4}$ turns is determined. The parachute is opened for the recovery attempts by actuating the remote-control mechanism and the rudder is held with the spin so that recovery is due to the parachute action alone. The parachute towline is generally attached to the bottom rear of the fuselage. The folded spin-recovery parachute is placed on the model in such a position that it does not seriously influence the established spin. A rubber band holds the packed parachute to the model and when released allows the parachute to be blown free of the model. On full-scale parachute installations it is desirable to mount the parachute pack within the airplane structure, if possible, and it is recommended that a mechanism be employed for positive ejection of the parachute.

Precision

Results determined in free-spinning tunnel tests are believed to be true values given by models within the following limits:

α, deg	± 1
ϕ, deg	± 1
V, percent	± 5
Ω, percent	± 2
Turns for recovery obtained from motion-picture records	$\pm \frac{1}{4}$
Turns for recovery obtained visually	$\pm \frac{1}{2}$

The preceding limits may be exceeded for certain spins in which it is difficult to control the model in the tunnel because of the high rate of descent or because of the wandering or oscillatory nature of the spin.

The accuracy of measuring the weight and mass distribution of models is believed to be within the following limits:

Weight, percent	±1
Center-of-gravity location, percent $\bar{c}$	±1
Moments of inertia, percent	±5

Controls are set with an accuracy of $\pm 1^{\circ}$.

Variations in Model Mass Characteristics

Because it is impracticable to ballast models exactly and because of inadvertent damage to models during tests, the measured weight and mass distribution of the F9F-6 model varied from the true scaled-down values within the following limits:

Weight, percent	0
Center-of-gravity location (horizontally), percent $\bar{c}$	0
Moments of inertia:	
I_X, percent	4 high to 5 high
I_Y, percent	1 high to 4 high
I_Z, percent	1 high to 2 high

Comparison Between Model and Airplane Results

Comparison between model and full-scale results in reference 6 indicated that model tests accurately predicted full-scale recovery characteristics approximately 90 percent of the time and that, for the remaining 10 percent of the time, the model results were of value in predicting some of the details of the full-scale spins, such as motions in the developed spin and proper recovery techniques. The airplanes generally spun at an angle of attack closer to 45° than did the corresponding models. The comparison presented in reference 6 also indicated that generally the airplanes spun with the inner wing tilted more downward and with a greater altitude loss per revolution than did the corresponding models.

REFERENCES

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2. Gale, Lawrence J.: Effect of Landing Flaps and Landing Gear on the Spin and Recovery Characteristics of Airplanes. NACA TN 1643, 1948.

3. Zimmerman, C. H.: Preliminary Tests in the N.A.C.A. Free-Spinning Wind Tunnel. NACA Rep. 557, 1936.

4. Neihouse, A. I.: A Mass-Distribution Criterion for Predicting the Effect of Control Manipulation on the Recovery From a Spin. NACA WR L-168, 1942. (Formerly NACA ARR, Aug. 1942.)

5. Neihouse, Anshal I., Lichtenstein, Jacob H., and Pepoon, Philip W.: Tail-Design Requirements for Satisfactory Spin Recovery. NACA TN 1045, 1946.

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TABLE I

DIMENSIONAL CHARACTERISTICS OF THE GRUMMAN F9F-6 AIRPLANE

Over-all length, ft	41.02
Wing:	
Span, ft	34.50
Area, sq ft	300
Incidence, deg	0
Dihedral, deg	0
Aspect ratio	4
Taper ratio	0.5
Tip chord, in.	69
Root chord, in.	137.98
Mean aerodynamic chord, in.	107.5
Leading edge $\bar{c}$ behind wing apex, ft	6.01
Sweepback at 25 percent chord, deg	35
Airfoil section	64A010
Flaperons:	
Span, ft, each (parallel to Y-axis)	8.45
Horizontal tail:	
Span, ft	14.16
Total area, sq ft	50
Sweepback at 25 percent chord, deg	35
Tail-damping ratio	0.0421
Unshielded-rudder volume coefficient	0.0196
Tail-damping-power factor	0.000825

[redacted]

TABLE II

MASS CHARACTERISTICS AND INERTIA PARAMETERS FOR LOADINGS POSSIBLE ON THE GRUMMAN F9F-6 AIRPLANE AND FOR LOADINGS TESTED ON THE $\frac{1}{24}$-SCALE MODEL

[Model values converted to corresponding full-scale values; moments of inertia given about the center of gravity]

No.	Loading	Weight, lb	Center-of-gravity location		Relative density, μ		Moments of inertia, slug-ft^2			Mass parameters		
			$x/\bar{c}$	$z/\bar{c}$	Sea level	25,000 feet	I_X	I_Y	I_Z	$\frac{I_X - I_Y}{mb^2}$	$\frac{I_Y - I_Z}{mb^2}$	$\frac{I_Z - I_X}{mb^2}$
	Airplane values											
1	Normal flight	15,600	0.243	-0.032	19.69	43.95	9,148	26,676	33,943	-304×10^{-4}	-126×10^{-4}	430×10^{-4}
2	Flight most forward center of gravity	15,600	.230	-.031	19.69	43.95	9,257	26,834	33,994	-305	-124	429
3	Center of gravity moved rearward and I_X increased approximately 45 percent	15,600	.300	-.027	19.69	43.95	13,354	25,981	37,363	-219	-197	416
4	Take-off	17,900	.254	-.040	22.59	50.44	13,488	27,280	38,708	-208	-173	381
	Model values											
1	Normal flight	15,543	0.244	-0.007	19.61	43.79	9,500	26,976	34,164	-304×10^{-4}	-125×10^{-4}	429×10^{-4}

[redacted]

TABLE III

SPIN-RECOVERY TAIL PARACHUTE DATA OBTAINED WITH THE $\frac{1}{24}$-SCALE MODEL OF THE GRUMMAN F9F-6 AIRPLANE

[Normal flight loading (loading 1 in table II); rudder fixed full with the spin and recovery attempted by opening the tail parachute only, except as noted; elevator set 30° up and stick set full left in a right spin; model values converted to corresponding full-scale values; C_D of parachutes approximately 0.70; towline attached below jet exhaust at rear of fuselage; right erect spins]

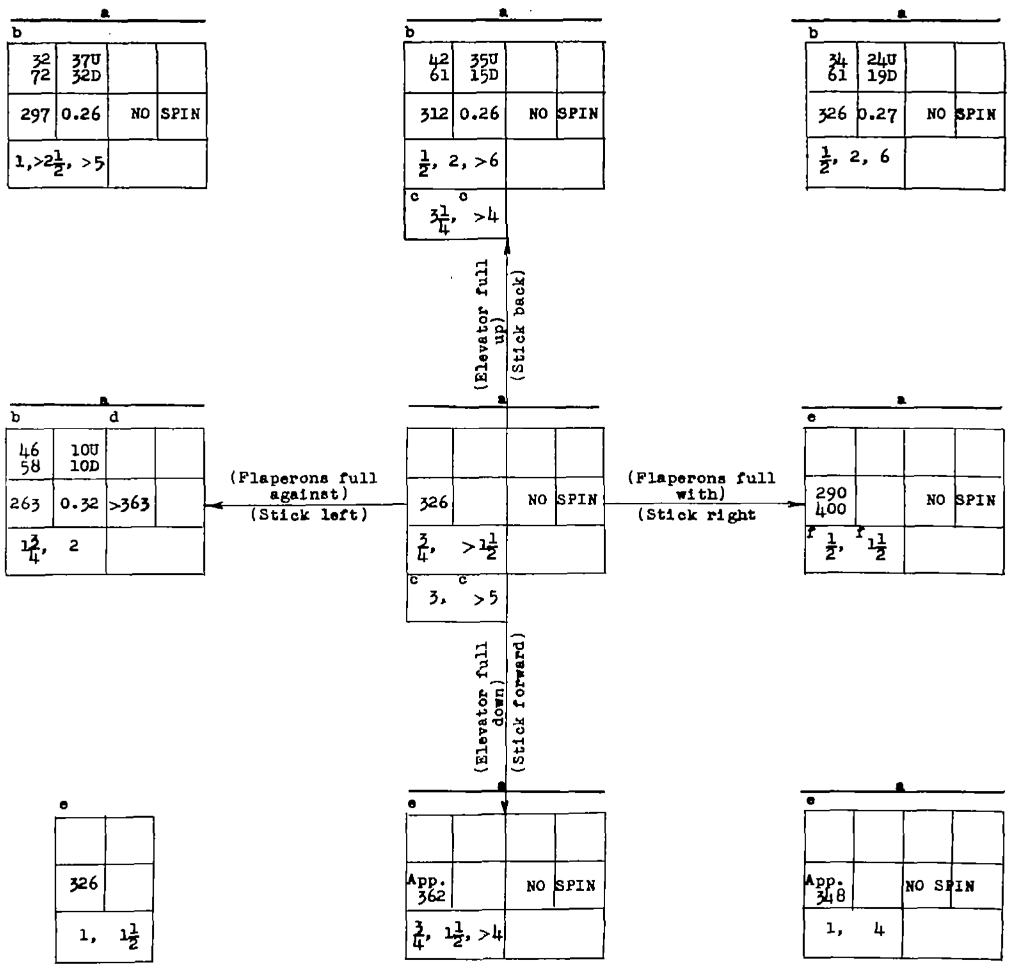
Parachute diameter, ft	Towline length, ft	Turns for recovery [a]
[b]9	17.2	$\frac{1}{2}$, $\frac{1}{2}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$
10	34.5	$\frac{1}{4}$, $1\frac{1}{2}$, >2, >$2\frac{1}{4}$, 3
11	17.2	$1\frac{1}{4}$, $1\frac{1}{2}$, 2, >$2\frac{1}{4}$, >$2\frac{1}{2}$
11	34.5	$\frac{1}{4}$, $\frac{3}{4}$, 2, >2, >$2\frac{1}{4}$
12	34.5	$\frac{1}{4}$, $1\frac{1}{4}$, >$2\frac{1}{2}$, >$5\frac{1}{4}$
13	17.2	$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{4}$
13	34.5	$\frac{1}{4}$, $\frac{1}{2}$, $\frac{1}{2}$, $1\frac{1}{2}$, 2
14	34.5	$\frac{1}{4}$, $\frac{1}{4}$, $\frac{1}{2}$, 1, $1\frac{3}{4}$

[a]Parachutes tended to foul on tail surfaces. Recovery data presented for those instances where parachutes did not foul.

[b]Parachute opening accompanied by full rudder reversal to against the spin.

CHART 1.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF MODEL

[Normal flight loading (loading 1 in table II); recovery attempted by full rapid rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder full-with spins); right spins]



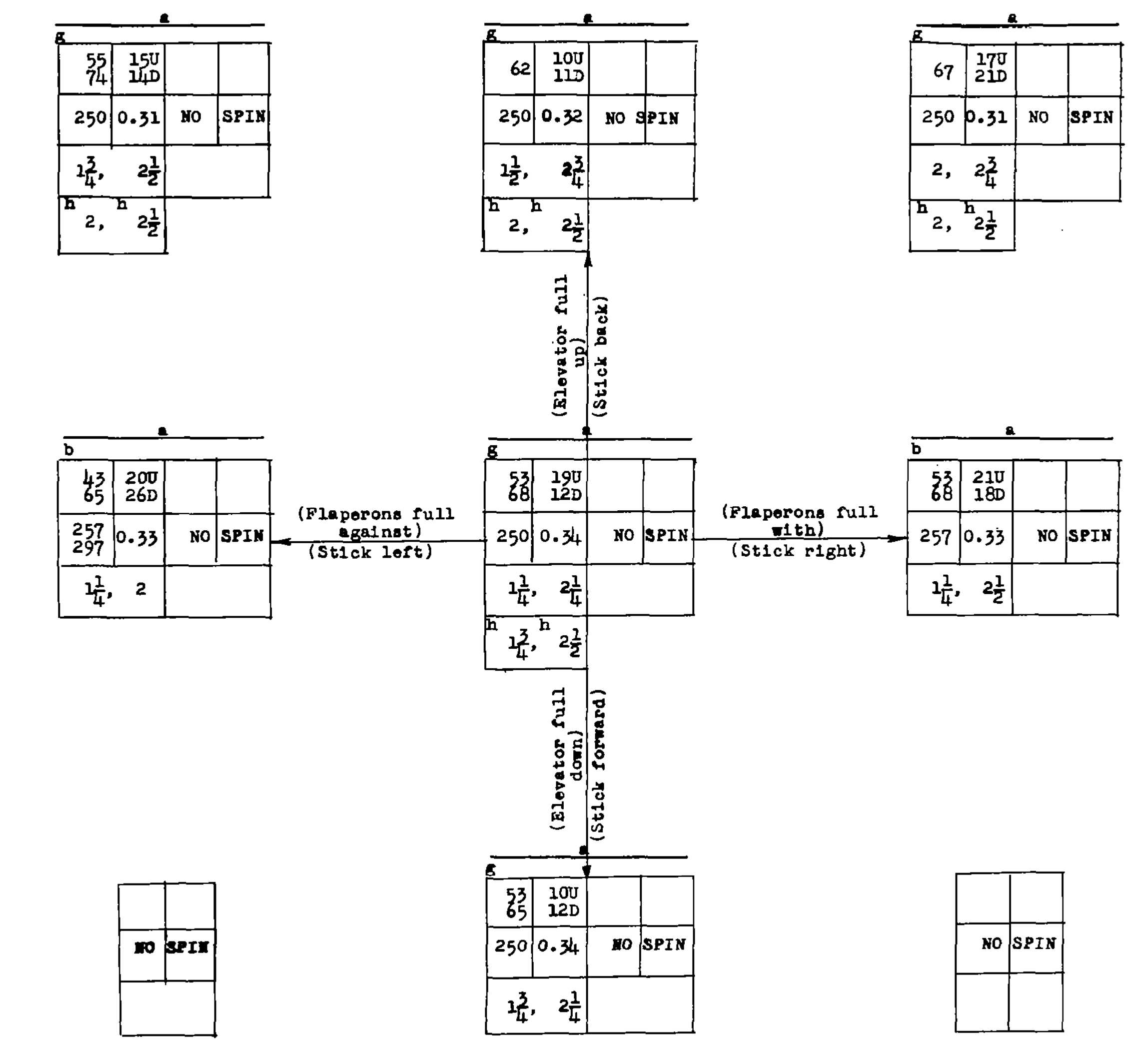
α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

[a]Two conditions possible.
[b]Spin oscillatory primarily in roll and yaw, range or average values given.
[c]Recovery attempted by simultaneous rudder neutralization and elevator movement to full down.
[d]Steep spin that cannot be maintained in tunnel.
[e]Model spins steeply then flattens out as rate of rotation increases and repeats; range or average values given.
[f]Recoveries attempted only from steeper attitude.
[g]Slightly oscillatory primarily in roll and yaw, range or average values given.
[h]Recoveries attempted by simultaneous reversal of rudder to full against the spin and movement of the elevator to full down.

CHART 2.- ERECT SPIN AND RECOVERY CHARACTERISTICS OF MODEL — SLATS EXTENDED

[Normal flight loading (loading 1 in table II); recovery attempted by full rapid rudder reversal except as indicated (recovery attempted from, and steady-spin data presented for, rudder full-with spins); right spins]



NOTE: Footnotes given on chart 1.

Model values converted to corresponding full-scale values.
U inner wing up
D inner wing down

α (deg)	φ (deg)
V (fps)	Ω (rps)
Turns for recovery	

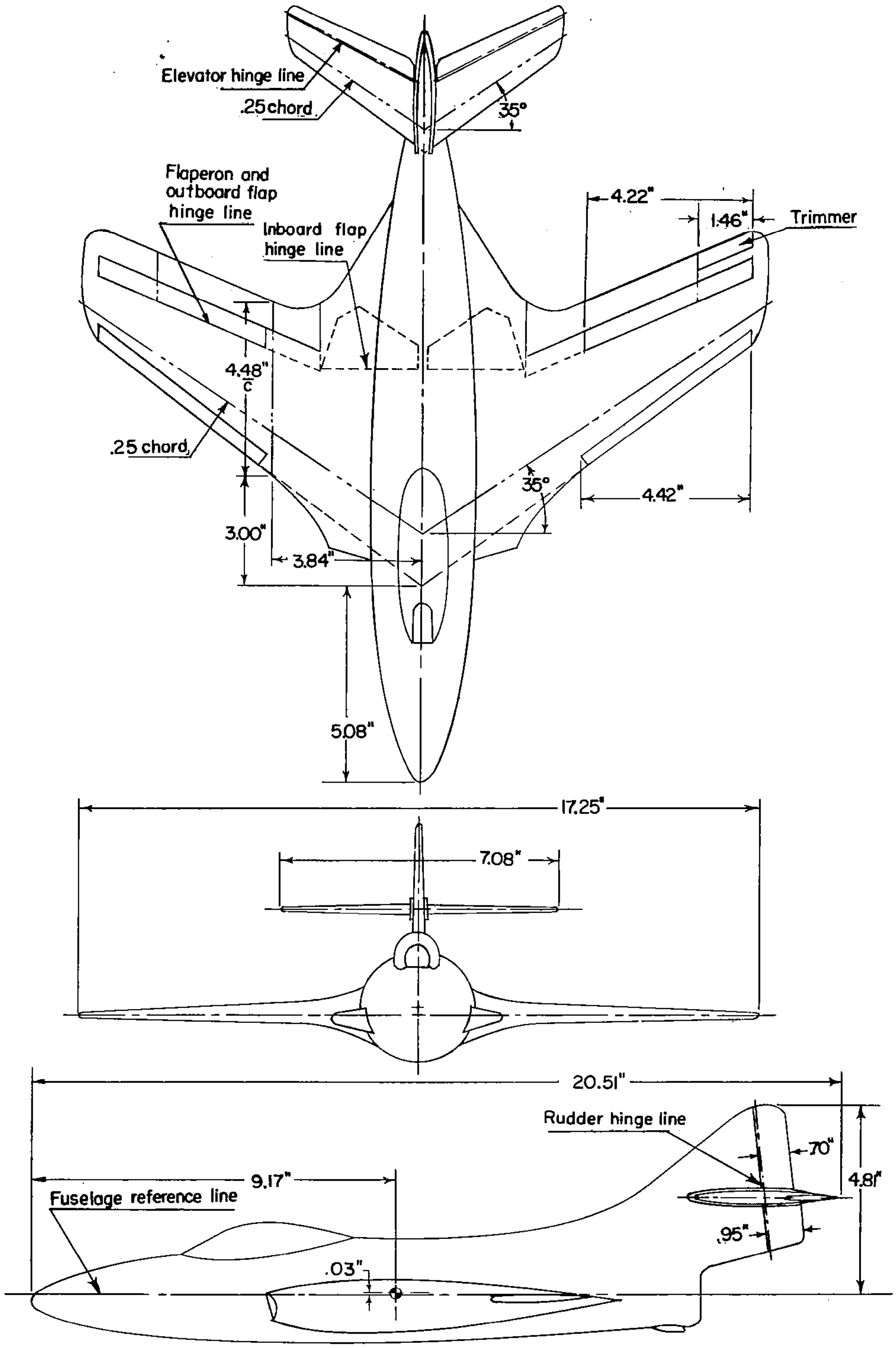


Figure 1.- Three-view drawing of the 1/24-scale model of the Grumman F9F-6 airplane. Center of gravity is shown for normal flight loading.

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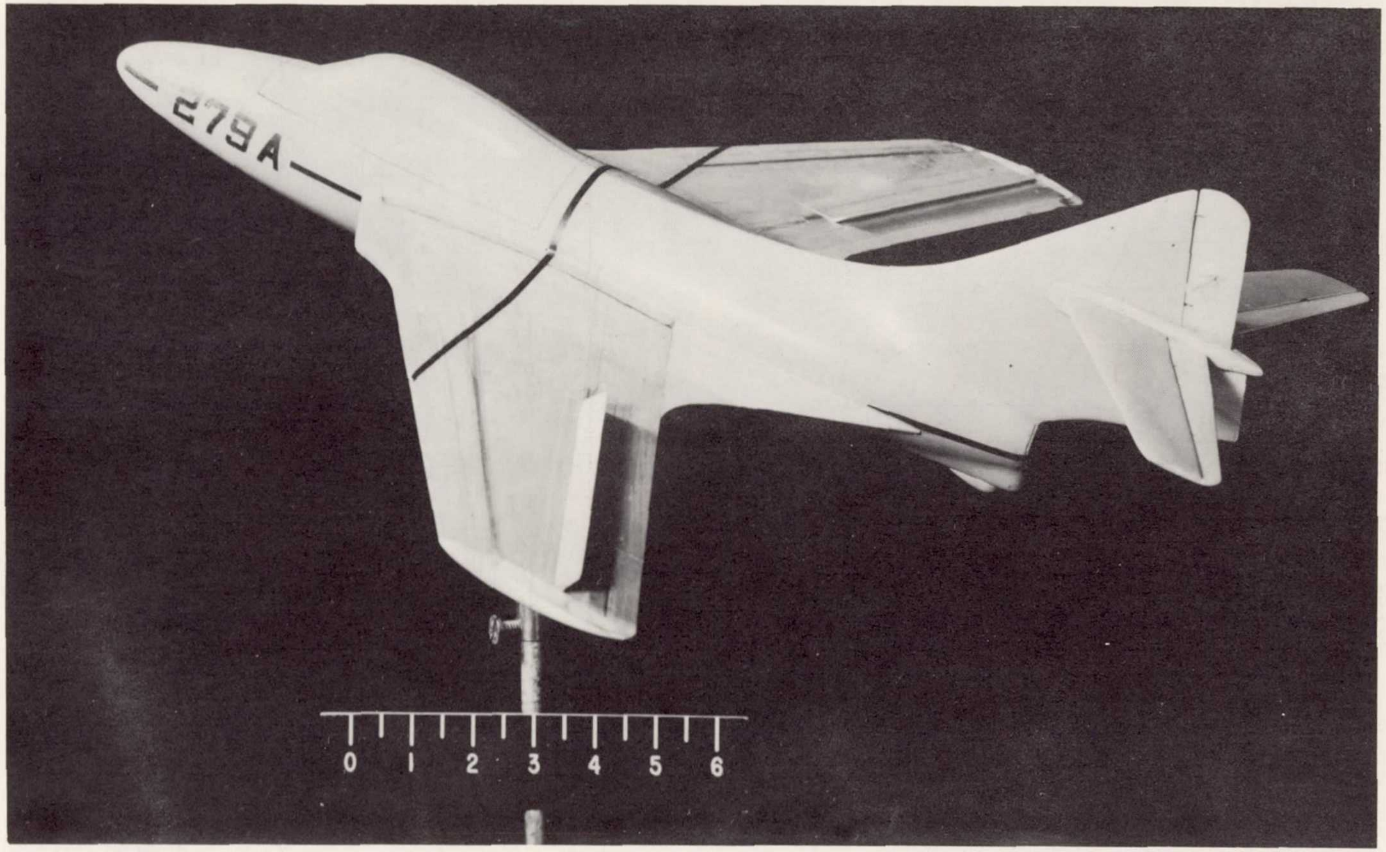

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Figure 2.- Photograph of the 1/24-scale model of the Grumman F9F-6 airplane showing the flaperons.

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